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http://www.azgs.az.gov
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ARIZONA DEPARTMENT OF MINES AND MINERAL RESOURCES AZMILS DATA

PRIMARY NAME: PERIDOT MINE

ALTERNATE NAMES:
PERIDOT OCCURANCE 38
PERIDOT OCCURANCE 37

GILA COUNTY MILS NUMBER: 113

LOCATION: TOWNSHIP 1 S RANGE 18 E SECTION 14 QUARTER W2
LATITUDE: N 33DEG 20MIN 21SEC LONGITUDE: W 110DEG 28MIN 30SEC
TOPO MAP NAME: SAN CARLOS - 7.5 MIN

CURRENT STATUS: PAST PRODUCER

COMMODITY:
GEMSTONE PERIDOT

BIBLIOGRAPHY:
BROMFIELD C S & A SHRIDE MIN RES SAN CARLOS IND RES USGS BULL 1027-N 1956 P 686
ADMMR PERIDOT MINE FILE
ALSO IN SECTION 22
AZBM BULL. 180, P. 360

05/23/86

ARIZONA DEPARTMENT OF MINES AND MINERAL RESOURCES FILE DATA

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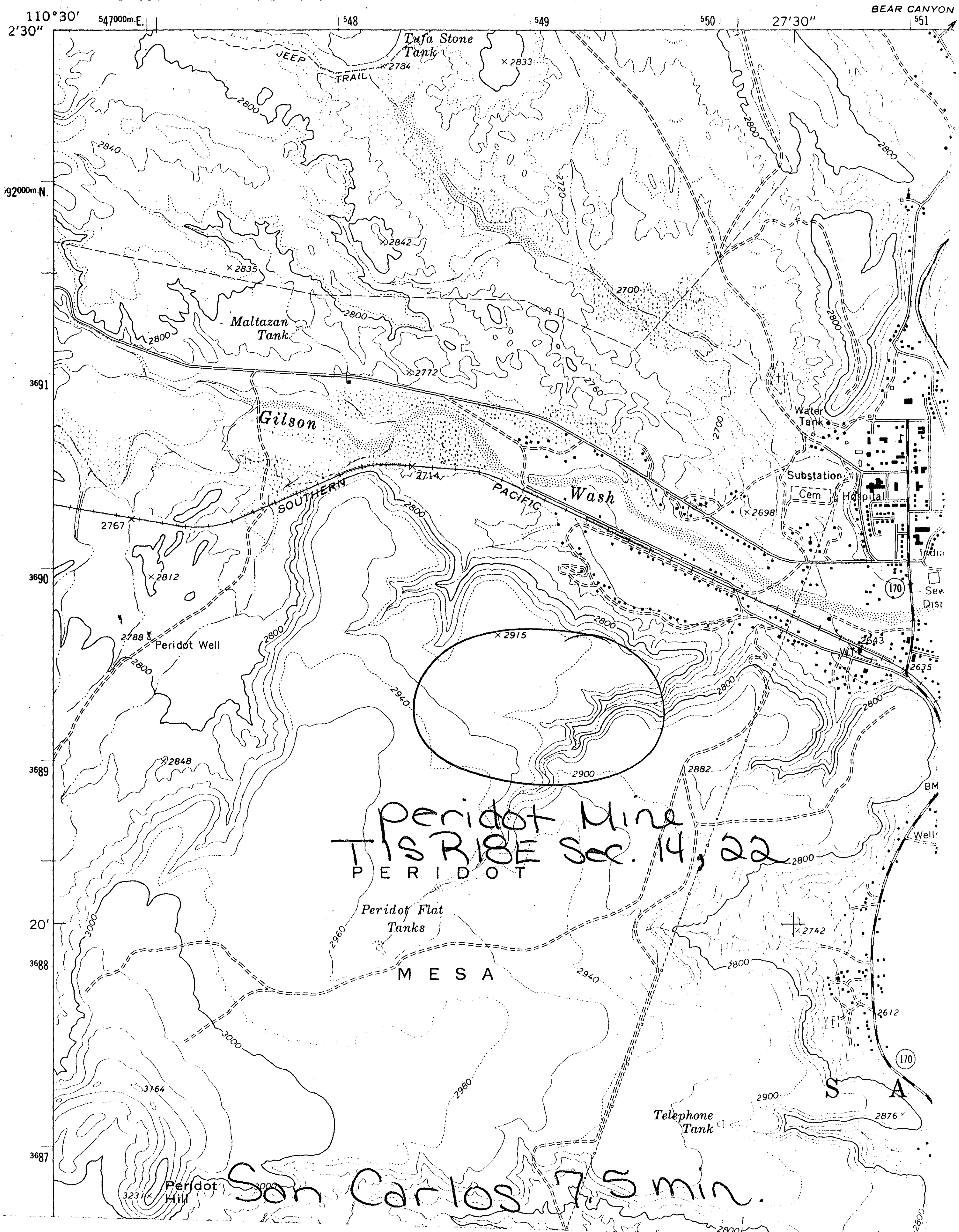
ALSO IN SECTION 22

DEPARTMENT OF THE INT[illegible]RIOR
GEOLOGICAL SURVEY



ARIZONA DEPARTMENT OF MINES AND MINERAL RESOURCES

# INFORMATION FROM MINE CARDS IN MUSEUM

GILA CO. CARD #1
SAN CARLOS ~~RESERV.~~

MILS # 113
Peridot mine (file)
2-AKA'2

| | |
|---|---|
| MM 8538 | Faceted Peridot |
| 8539 | Faceted Peridot |
| 8540 | Ring 3 Peridot |
| 8535 | Olivene var. Peridot 15# |
| 8536 | bag of Peridot pebbles 1#12oz |
| 8537 | bag of tumbled Peridot 1#11oz |
| 8541 | Ring faceted Peridot |
| 8542 | Ring 2 tumbled Peridot |
| 8543 | Ring Peridot tumbled |
| 8544 | Ring 3 tumbled Peridot |
| 8545 | Earrings tumbled Peridot |
| 8546 | Broach Tumbled Peridot |
| 8547 | Bracelet 7 tumbled Peridot |
| 8548 | Indian carrying Basket |
| 8549 | Ring tumbled Peridot |
| 8550 | Olivine var. Peridot 1.4 oz. |
| L 722 | Olivine peridot |
| L 723 | " peridot |
| L 724 | Olivine Peridot |
| L 725 | |
| L 726 | Olivine " |

ARIZONA CARD #2

GILA COUNTY
SAN CARLOS ~~INDIAN RES.~~ #2

MILS #113

| | |
|---|---|
| MM 4014 | Peridot |
| MM 4015 | Peridot |
| 4016 | Peridot |
| 4017 | Peridot |
| 4289 | Peridot |
| 4290 | Peridot |
| MM 6179 | Peridot, faceted |
| 6833 | Peridot, faceted |
| 1874 | Building stone |
| MM K829 | Peridot |
| L 717 | Olivine peridot |
| L 718 | " " |
| L 719 | " " |
| L 720 | " " |
| L 721 | " " |
| M 482 | " " |
| M 483 | " " |
| M 484 | " " |
| M 485 | " " |
| M 486 | " " |

ARIZONA DEPARTMENT OF MINES AND MINERAL RESOURCES

# INFORMATION FROM MINE CARDS IN MUSEUM

Az., Gila Co. # 3

San Carlos ~~District~~ #3

MILS #113

| | |
|---|---|
| MM M 533 | Peridot |
| 534 | " |
| 535 | " |
| 536 | " |
| 537 | " |
| 538 | " |
| 539 | " |
| 540 | " |
| 541 | " |
| 542 | " |
| 543 | " |
| 544 | " |
| 545 | " |
| 546 | " |
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| 549 | |
| 550 | |
| 551 | |
| 552 | |
| 553 | " |

Arizona, Gila Co. # 4

San Carlos #4

MM M 964 Peridot
M 965 "

MILS #113

| | |
|---|---|
| MM M 554 | Peridot |
| 555 | " |
| 556 | |
| 557 | " |
| 558 | |
| 559 | |
| 560 | |
| 561 | |
| 562 | |
| 563 | |
| 564 | |
| 565 | |
| 566 | |
| 567 | |
| 568 | |
| 569 | |
| 570 | |
| 571 | |
| 572 | |
| 573 | |
| 574 | |
| MM M 963 | Peridot |

ARIZONA DEPARTMENT OF MINES AND MINERAL RESOURCES

# INFORMATION FROM MINE CARDS IN MUSEUM

ARIZONA #5
GILA CO
San Carlos #5

MM M 595 Peridot
M 596 "
M 597 "
M 598 "
M 599 "
M 600 "
M 601 "
M 602 "
M 904 Peridot

MILS #113

MM M 574 peridot
575 "
576 "
577 "
578 "
579 "
580 "
581 "
582 "
583 "
584 "
585 "
586 "
587 "
588 "
589 "
590 "
591 "
592 "
593 "
594 "
MM M 125 Garney

PERIDOT MINE GILA COUNTY

NJN WR 10/31/86: Jim Crowther, mining engineer with the Bureau of Indian Affairs, reported that Rawley Thompson, resource chairman for the San Carlos Indians is the official contact for gem peridot sales from the reservation (Peridot Mine - file) In the recent past peridot buyer, Carl Minas, tried to organize the peridot mining, rock hound collecting, etc on the reservation. The Indians in general resisted this and the attempt has now been abandoned. Apparently, some individuals do not want to give up the black market sales. Another problem is that although the Tribal Council likes the idea of getting Federal funding for the project, they fail to provide the necessary maintenance, supervision, etc to make the project successful. Current production is by occassional gophering and blasting by individuals.

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# FIELDNOTES FROM THE ARIZONA BUREAU OF MINES

Vol. 7 No. 2 Earth Sciences and Mineral Resources in Arizona Summer 1977

# We're Changing Our Name!

Summer 1977 FIELDNOTES will be the last publication from the Arizona Bureau of Mines. On August 27, 1977, our name will change, our organizational format will be revised, and our duties updated.

Governor Raul Castro signed House Bill 2060 on May 26, which changes the Arizona Bureau of Mines into the Bureau of Geology and Mineral Technology, and revises the original 1915 charter. The main points of HB 2060 are:

**New name: Bureau of Geology and Mineral Technology**

The Bureau's new name better describes the actual function of this agency. As the Arizona Bureau of Mines, our geological survey and research functions were not easily recognized by those to whom we could be of service.

**Division of the University of Arizona**

Under the new charter, the Bureau is a division of the University reporting directly to President Schaefer. Previously, the Bureau had been a department, but in theory reported directly to the Board of Regents; in practice, though, the Bureau had been under the direction of the University President since 1918.

**Director's qualifications changed**

The Bureau's Director, under the 1915 laws, "must" be a mining engineer. House Bill 2060 changed this to include geologists and geological and metallurgical engineers, and to require registration by the Arizona Board of Technical Registration.

**Two separate branches created**

The dual roles of the Bureau were emphasized by the official creation of a Geological Survey Branch and a Mineral Technology Branch. An assistant director is to be appointed to head each branch: a registered geologist or geological engineer will head the Geological Survey Branch, and a registered mining or metallurgical engineer will head the Mineral Technology Branch. In addition, the assistant director in charge of the Geological Survey will officially become the State Geologist.

**Goals and duties updated**

The Bureau's goals were redefined in keeping with other state geological surveys. In brief, our duties now include:

1. The investigation, description, and interpretation of the geology of the State, including natural hazards and mineral resources.
2. Conducting research into the exploration, mining, and processing functions of mineral resource production.
3. Publishing the results of our research and investigations.
4. Providing lectures, displays, and exhibits to the public.
5. Maintaining a central repository, or library, of geological and mineral technological publications, and making it available to the public.
6. Maintaining a well cutting and core repository.

We already supply all of these services, although our 1915 charter did not make specific allowance for them.

According to that charter, though, our duties included the maintenance of a "mine rescue car" and the teaching of first aid and safety classes. The State Mine Inspector's office, since its inception, has carried out the safety functions, and we have not been able to locate or identify a mine rescue car during the 62 years of our existence.

# Bureau Studies Olivine Resources On San Carlos Apache Reservation

by John S. Vuich and Richard T. Moore

This article is extracted from a recently completed report compiled by the ABM in cooperation with the University of Arizona Office of Arid Lands Studies. The project was undertaken at the request of the San Carlos Apache Tribe.

The objectives of the study were fourfold:

1. Evaluate the source materials, an olivine-rich basalt flow on Peridot Mesa.
2. Suggest efficient methods of mining and beneficiation.
3. Determine the types of products that might be marketed.
4. Investigate the extent of the market that might exist for the potential products.

This abbreviated report includes most of the geologic description and product evaluation/market survey contained in the original report. Missing here are the lab procedure description and analysis tables, the glossary of terms, and the recommended methods for mining and beneficiation. The complete report may be seen in the library of the Bureau's Geological Survey Branch or at the Office of Arid Lands Studies, both located at 845 North Park Avenue, Tucson.

**John S. Vuich, Assistant Geologist, and Richard T. Moore, Principal Geologist, are with the Arizona Bureau of Mines, Geological Survey Branch.**

## Geology

*General Geologic Statement*

The olivine-bearing volcanic flow is basaltic in composition. Virtually all olivine on Peridot Mesa is contained in this single flow. Subsequent eruptions of scoria spatter and scoriaceous flows

*Continued on page 6*

**Olivine Resources Study** *Continued from page 1*

contain small amounts of olivine. A semicircular dike system on Peridot Hill appears to be the source of both the main basalt flow and the scoria eruptions. All scoria flows are confined to the area immediately surrounding Peridot Hill. They drape over the earlier basalt flow and underlying sedimentary rocks. The original extent of the basalt flow was probably twice the present exposed surface area. Small erosional remnants of this flow cap portions of mesas and ledges immediately to the north, south, and east of Peridot Mesa (Geologic Map, Fig. 1). A reconnaissance of the surrounding region did not reveal other olivine-bearing rocks of any significance; therefore, the Peridot Mesa flow is considered to be the only volcanic rock worth exploiting.

*Olivine Formation*

The origin and history of the olivine material began in a molten-rock chamber. Olivine was one of the first substances to crystallize and collect in this molten rock mixture, probably as a layer of granular, crystalline matter. A subsequent fissure-eruption of this molten mixture broke the olivine layer into small fragments which outpoured with the eruption. As the molten rock flowed on a surface of sedimentary rocks, the olivine fragments tumbled and rolled with it, gradually settling to the bottom while much of the flow was still viscous. Later eruptions were scoriaceous and local in extent. Figure 2 shows the sequential development of Peridot Mesa with a dike representing the basalt-filled fissure from which the eruptions issued.

*Peridot Mesa Description*

Sedimentary rocks underlying Peridot Mesa consist of water-lain (?) tuffs, tuffaceous siltstones, sandstones, and conglomerates. These rocks are essentially flat-lying bedded sediments upon which the Peridot Mesa flow rests. The upper beds contain small quantities of olivine bombs (Lausen, 1927) from pre-flow eruptions.

On Peridot Mesa, the average basalt flow thickness is estimated to vary from 10 feet to 60 feet. Local channel-fill sections are thicker. Headward erosion of Peridot Canyon drainage has conveniently removed some of the flow surface in the vicinity of the Main Pit workings. Here the flow has been eroded to approximately 5 feet in thickness. Remant-flow margins thin northeasterly in the outlying mesa outcrops. Rock structures on Peridot Mesa such as flow wrinkles and lava-lobe shapes suggest that the general flow trend was northeasterly. Figure 3 is a diagram of typical features seen in cross section of the olivine-bearing basalt flow.

The basalt flow is in contact with lakebed sedimentary rocks. Bottom surfaces of the volcanic rock are generally marked by a scoriaceous flow-breccia. The irregular nature of this cindery breccia zone often contains blocks of underlying sedimentary rocks and inclusions of olivine. Above the flow-breccia is the olivine zone.

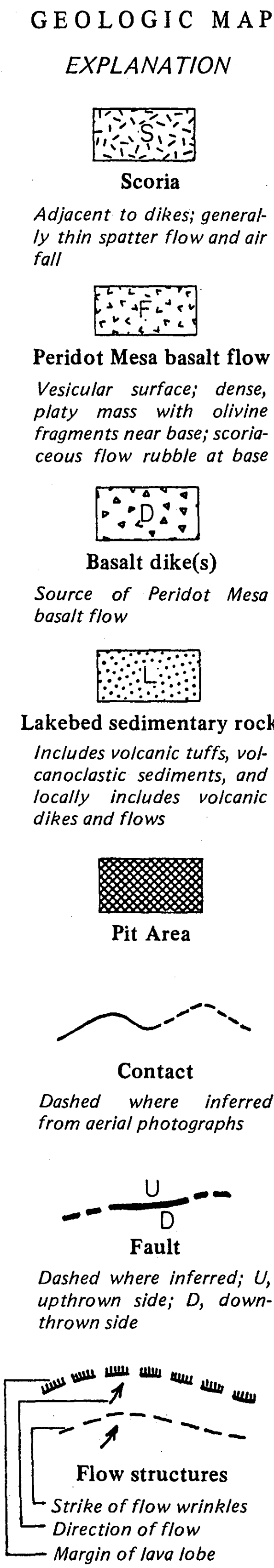
*Physical Characteristics and Distribution of Olivine*

Some general features were noted concerning the olivine size and distribution within the flow. Much of the olivine is granular in texture, analogous to a mixture of fine-sized gravel and coarse-grained sand. The small masses of granular olivine are varied in their size and shape, depending on their cohesiveness and the forces to which they were subjected during transportation and settling within the flow. Some blocks are rounded and others are angular or oblong (Figure 4). The blocks are commonly 2-6 inches across while some larger masses up to 18 inches in diameter were noted. In any given section, the larger olivine lumps congregated by settling near and at the bottom of the lava flow. Upper portions of the olivine zone contain progressively fewer olivine blocks and their respective diameters are commonly less than 3 inches. The overall olivine content and block size decreases northeasterly as the olivine zone thins toward the flow margins. In the central area of Peridot Mesa, from the Main Pit location to the North Pit, the olivine zone thickness is estimated to vary from 1.5 to 5 feet and contain upwards from 60 to 70 percent olivine. Barren basalt above the olivine zone is from 5 to 10 feet or more in thickness. Along the north margins of Peridot Mesa, and along the basalt flow exposed in the cliffs above the San Carlos River's east bank, the olivine zone locally increases in thickness to 15 feet. Here, however, the olivine content is even lower, being less than 10 percent, and the granular masses are commonly less than 4 inches in diameter. Basalt overburden above these olivine zones has increased to 20-30 feet. Although all the exposures of the original flow margins examined contained some olivine blocks, these minimum zones were estimated to have an overall content of only 2 percent olivine occurring in granular masses of from 1 to 2 inches in diameter.

*Mineral Reserves*

From observed quantities and distribution of olivine it is estimated that 80 percent of the original olivine volume remains on Peridot Mesa and in the erosional remnants of the basalt flow. We would also conclude that all presently exploitable olivine resources lie on

Continued on page 8



*Continued from page 6*

Peridot Mesa (Mineral Reserves Table – Geologic Map, Fig. 1). In order to maintain a reasonable stripping ratio of overburden to ore from 0.5:1 to 2:1, it appears that the olivine zone should maintain a minimum olivine content by volume of 30 percent. This figure is based on olivine distribution and flow geometry. Mining methods and market/product valuations certainly would be a basis for revision of this olivine content estimate. The Mineral Reserves Table (Table 1) is our best estimate of the probable extent of the 30 percent olivine zone. Our best estimate of the area of a higher-grade ore zone containing 50 percent olivine is shown within the 30 percent zone.

An example of a shallow olivine zone with an approximate stripping ratio of 0.5:1 lies along the West Rim excavations, and at the North Pit the ratio is approximately 1:1. Deeper olivine zones with a stripping ratio of 2:1 and locally 5:1 are exposed along the east rim excavations of Peridot Canyon. The Main Pit workings lie partly in an erosional depression at the head of Peridot Canyon drainage. This is an example of how erosion has partially removed the basalt overlying the olivine zone, and thus contributed to the inconsistency of overburden thicknesses.

Based on field observations and assumptions defined on the olivine reserves chart (Mineral Reserves Table 1), it is estimated that approximately 1,100 acres of Peridot Mesa contain over 19 million tons of "ore" in which there is nearly 8 million tons of olivine and over 11 million tons of basalt. Above this "ore zone" lie over 33 million tons of essentially barren basalt at an average stripping ratio of 1.7:1.

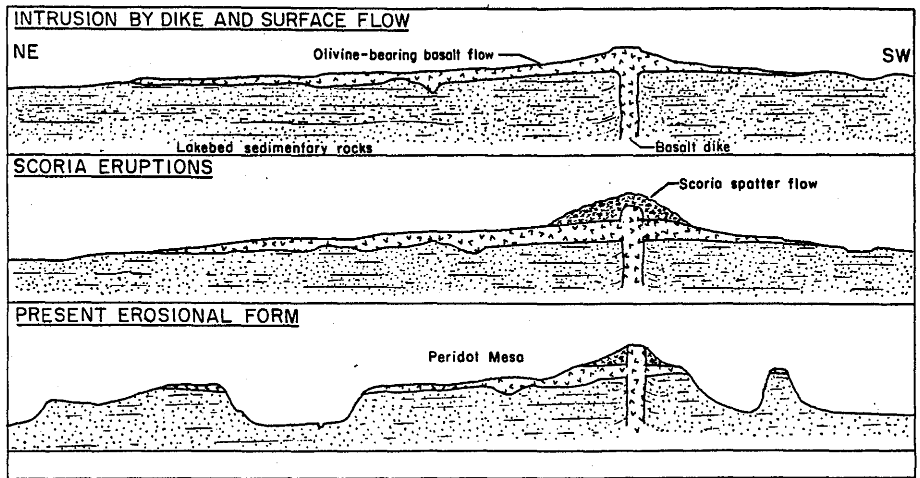



Figure 2 Generalized cross-section of Peridot Mesa area. Northeast — southwest section; view is easterly. Historical development is interpretive. Not to scale.

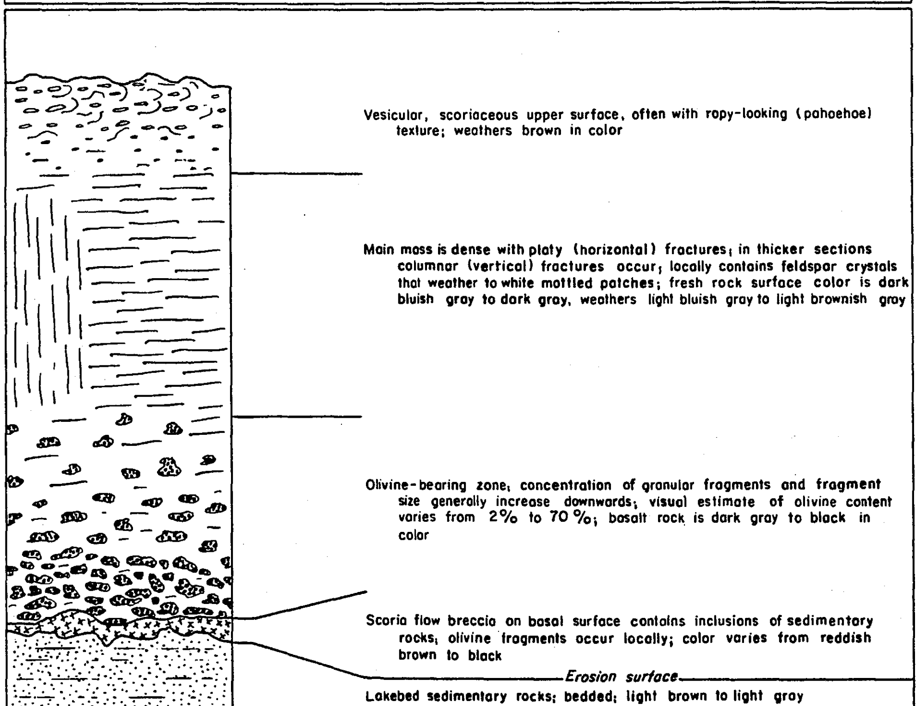



Figure 3 Generalized column through the Peridot Mesa basalt flow. Not to scale

### Product Evaluation and Market Survey

*Gem Peridot*

Gem peridot has been produced from Peridot Mesa for many years and is a logical product for first consideration in any evaluation and market survey.

The olivine on Peridot Mesa, as previously indicated, occurs as nodules and irregularly shaped masses of granular material. The value of the olivine as a gem stone is dependent upon the size, clarity, and shadings of color of the individual granules. Granules under approximately ¼ inch in diameter, or having internal fracture planes; granules which are cloudy or contain inclusions; and granules of excessive darkness or paleness of color all are of little value.

In past years, the individual operators sold their peridot production in various grades, depending upon size, and prices ranged from $1.50 to $8.00 per pound. More recently, however, the tendency has been to sell unsorted material (other than the initial sorting at mine site) at an intermediate price of from $4.00 to $4.50 per pound. With the increase in this practice, there has been a tendency among some of the operators to dilute their product with considerable worthless material because it is not easily detected under casual examination in the ungraded material. The result of this rather questionable practice has been to make a number of the buyers interviewed quite critical, and this could eventually work to the disadvantage of all the operators.

Apparently, no records are currently being kept on the amount of peridot being produced and it was not possible to determine this accurately through questioning of the operators. On the basis of what could be observed, however, we crudely estimate that between 1,600 and 2,400 pounds per month of rough peridot is being marketed from the Mesa. Of this, probably less than 7 percent actually remains as salable material after processing into faceted and tumble-polished gem stones, and by far the major portion of the finished stones are in the lower-priced tumble-polished category.

Tracing the trail of raw peridot from the mine to the principal "brokers" is a difficult task – the business is very competitive and few of the traders and dealers are willing to discuss their individual arrangements. An overall picture of the market process, however, has been pieced together from numerous sources.

In general, two categories of buyers

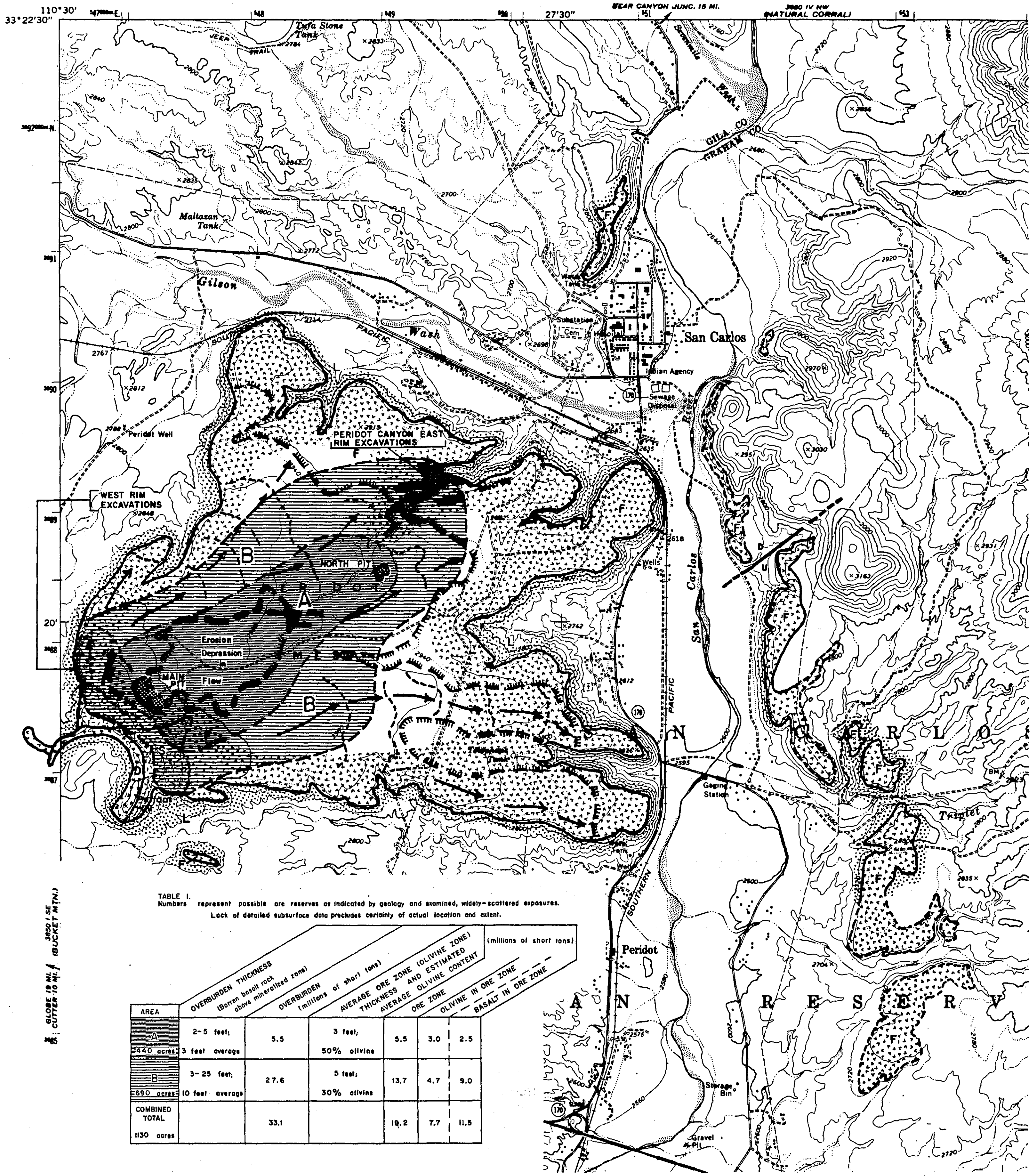



TABLE I.
Numbers represent possible ore reserves as indicated by geology and examined, widely-scattered exposures.
Lack of detailed subsurface data precludes certainty of actual location and extent.

| AREA | OVERBURDEN THICKNESS (Barren basalt rock above mineralized zone) | OVERBURDEN (millions of short tons) | AVERAGE ORE ZONE (OLIVINE ZONE) THICKNESS AND ESTIMATED AVERAGE OLIVINE CONTENT | ORE ZONE (millions of short tons) | OLIVINE IN ORE ZONE (millions of short tons) | BASALT IN ORE ZONE (millions of short tons) |
|---|---|---|---|---|---|---|
| A 440 acres | 2–5 feet; 3 feet average | 5.5 | 3 feet; 50% olivine | 5.5 | 3.0 | 2.5 |
| B 690 acres | 3–25 feet; 10 feet average | 27.6 | 5 feet; 30% olivine | 13.7 | 4.7 | 9.0 |
| COMBINED TOTAL 1130 acres | | 33.1 | | 19.2 | 7.7 | 11.5 |

SAN CARLOS QUADRANGLE

7.5 minute series

scale 1:24,000

0 1000 2000 3000 4000 5000 FEET

Fig. 4. Detail features of olivine zone, North Pit. Olivine blocks are "salt and pepper" granular masses; the basalt is dark and partially vesicular. Lens cap is 2.5 inches in diameter.

can be identified. The first is the individual who may be either an amateur gem and mineral collector or a small dealer who is engaged in resale to amateur collectors, gem cutters, and lapidaryists. The second category is the larger dealer, or broker, who buys in somewhat larger quantities from several different sources and then resells the material into the commercial market.

Buyers in the first group generally deal directly with the operators, either at the mines or at the operators' homes. Although there is considerable overlap in the method of operation of the various buyers, the broker more often operates out of a fixed business establishment and acquires the major portion of his peridot from operators and other, smaller buyers who come to his establishment with bulk material for sale. At this point in the market process, prices are rather well established in the $4.00 to $4.50 per pound bracket. An exception to this is the case where an intermediate buyer may do some additional sorting to produce a higher quality material, which of course then demands a higher price.

The next step involves the first really careful sorting to which the major portion of the peridot will have been subjected. The broker sorts the material into the poorer quality fraction, which is useful only for tumbling and the production of baroque jewelry, and into the much smaller fraction of high-quality stones which are set aside for faceting. The greater proportion of the faceting-grade material is shipped to any of several foreign countries for faceting. These are, in the order of quality of workmanship, primarily Germany, Korea, Hong Kong, Taiwan, Burma, and India; the exception to this, of course, is the peridot that is faceted in this country by the many amateur lapidaryists.

The market in faceted stones operates in either one of two principal fashions. Many of the major gem wholesalers, for instance those quartered in Los Angeles and New York, do not deal in uncut peridot. They buy directly from the gem cutters in Germany, Korea, etc., and the quality of the material they demand, of course, depends on their reputation and the size of their business. Typically these dealers pay from $7.50 to $15.00 per carat for faceted peridot, depending upon the size and quality of the stones. The second procedure that is followed by the major brokers who deal almost exclusively in peridot is to send shipments of 15 to 20 thousand stones at a time to various of the gem cutters with whom they do business for cutting and shipment back. In this case, the cutters are paid a previously agreed-upon price for cutting services only, as the broker already owns the peridot. Prices arrived at by these arrangements are extremely competitive and it was impossible to get any factual data on them. A problem that does occur with this method, however, was discovered; that is, in a shipment of 20 thousand stones for cutting often only 10 or 15 thousand stones might be returned, and usually no explanation is given. Some of the material may not have been facetable, or there is the obvious possibility that the material was retained by the cutters strictly for their own resale. Another problem sometimes encountered is the faceting of stones with fractures or other imperfections. When this happens, the owner is still charged the cutting fee but he does not receive a stone of salable quality.

Peridot that goes into the tumble-polished circuit may be either treated in the brokers' own shops or shipped overseas for polishing, drilling, and transhipment back. Such material wholesales at between $.50 and $.75 per carat, polished and drilled, and therefore must be considered a low-priced commodity.

Typical wholesale prices for various other peridot gem forms are as follows: 16" strands of tumbled and drilled stones range from $10 to $15 each; faceted stones of good quality will sell for from as little as $1.75 each for a 4-millimeter round-cut up to as much as $30 each for a fair to good 10 by 8 millimeter oval.

The major portion of world production of gem peridot, in terms of value, has been produced from Sri Lanka (Ceylon) and Egypt. Of secondary importance are Burma, Australia, Brazil, and the United States. Lesser quantities, although of commercial importance, have been obtained from India, Rhodesia, Namibiya (South-West Africa), Tanzania (Tanganyika), South Africa, Chile, Colombia, Uruguay-Paraguay, Canada, and Mexico. In the United States, Arizona and New Mexico are the principal areas of production. Although considerable world supplies would seem to be available for exploitation, it was the general consensus of the jewelers interviewed that the world market is capable of absorbing any reasonable amount of peridot that can be produced from the San Carlos Indian Reservation.

*Commercial Products*

Field examination of the olivine deposits on Peridot Mesa and extensive conversations with the Tribal members currently mining peridot on the mesa indicate that less than 1 percent of the olivine is of gem quality. However, inasmuch as it is necessary to handle all of the olivine in order to sort out that of gem quality, it was felt that it would be very desirable to develop, if possible, a market for the other 99 percent of the material to help cover the expenses of handling. With this is mind, a study was made of the commercial uses of olivine.

Our study indicates that relatively few commercial uses for olivine have been developed. Olivine sand is used principally as a refractory material in fire brick and foundry sand, and in the manufacture of magnesium phosphate as a fertilizer. Because of the lack of readily available supplies of phosphate material in the Arizona area, the use of olivine from Peridot Mesa in fertilizer is discounted at this time.

The use of olivine as a refractory is based on several of its physical and chemical properties. For instance, olivine is a high refractory material with a sinter point of between 2,850° and 2,900°F. and a fusion point in excess of 3,000°F. This property of the material gives rise to numerous uses in the refractory industry, such as block olivine for furnace linings, crushed olivine mixed with a binder for refractory brick manufacturer, ladle linings, patching compounds, and ramming mixes. Another use of olivine with a direct relation to its refractoryness, and potentially the most important in the terms of tonnage used, is in the field of foundry molding sands. Considerable research effort, both in this country and in Europe, has been applied in an effort to delineate the advantages and limitations of a manufactured olivine foundry sand.

Several foundries in the Tucson and Phoenix area use olivine sand as a foundry sand, and the bulk of this material is imported from Washington State.

Tests performed in the Arizona Bureau of Mines laboratories indicate that material derived from Peridot Mesa can be treated, and a probably usable foundry sand produced.

Although varying somewhat from the screen analyses of material currently being marketed in Arizona as foundry sand, it is quite probable that material of this general consistency could be used successfully. The actual determination of this, however, can only be made by submitting samples to several of the current users of olivine foundry sand for their experimentation. Currently, olivine foundry sand used in Arizona is being quoted at $5.60 per hundred pounds, sacked.

If a commercially acceptable product is made, there would seem to be no reason why it could not compete successfully in the southern California market area.

A second potential application of olivine, which to our knowledge has not been used commercially in this country, is as a decorative material in precast architectural concrete shapes.

This potential was discussed with two producers of precast shapes in the Phoenix area. We estimate that at a price of $60 per ton in 100-pound sacks, the olivine could be competitive with decorative aggregates that are now being used.

### Recommendations

After evaluating the role the San Carlos Tribal Government should take in the mining, beneficiation, and marketing of olivine, based on the information so far developed, we would make the following recommendations:

1. A Tribal industry based on the production of peridot is feasible. It should, however, be established as an addition to the existing operations and not be designed to take them over.
2. The industry should be established first to produce rough gem peridot only, and not be expanded into the production of commercial olivine products until markets for them can be assured.
3. The Tribal industry should consist primarily of producing raw, graded peridot on a wholesale basis. Although the production of tumble-polished material is a valid goal, the Tribe should not become involved in the production of domestically cut or faceted stones.

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## Water and the Mineral Industry *Continued from page 4*

significant problems are indicated for Maricopa, Apache, Coconino, Navajo, Yuma, and Santa Cruz Counties. The combined 2020 high projection for these six counties, as shown on Table 6, is only 20,000 acre feet per year or less than one percent of the currently developed dependable supply. However, some of the remaining counties can anticipate intense competition from the mining industry for the available water supplies. Mineral industry depletions in Pima County were estimated to be 53,000 acre feet in 1970. In both the high and medium projection, depletions would double by 1990 and, in the low projection, depletions would increase by approximately 50 percent by that year. As the current dependable supply is only 72,000 acre feet per year, Pima County faces a demand from this one industry well in excess of its dependable supply. The high projection for 2020 indicates that demand could be more than three times the supply currently available to all of Pima County on a dependable basis.

In Yavapai County, depletions in the mineral industry might increase to a level almost 10 times current use. Much of the future water use will be in the Bagdad area with supplies imported from Mohave County. A project is now under construction which will convey water from the Big Sandy Valley to Bagdad, and the mining company has requested a contract for 20,000 acre feet per year of Colorado River water. In general, the water supply situation in Yavapai County is relatively unclear, but the relationships between the projections and what is known about water supply indicate a potential problem and a need for additional study.

The absolute increase between the 1970 level of depletions by the mineral industry and the 2020 high projection for Pinal County is 188,000 acre feet of water. While the Pinal County relationship between projected demand by the industry and current dependable supply is more severe than in Pima County, competition for the supply will be less pronounced as urban requirements are expected to be considerably lower.

In Gila County the mineral industry is forecast to continue as the principal water user. By 1990 more than 80 percent of total county water depletion is projected to be by the mineral industry and by 2020 this will have increased to more than 90 percent. There is very little competition between mineral uses and agricultural uses in Gila County but only because agricultural usage is so small. In Greenlee County the mineral industry is forecast to realize large increases in water use causing severe water deficiencies. The high projection results in the mineral industry alone depleting an amount of water three times the current total dependable supply. Even the demand under the low projection would create severe competition for the limited supply available. It is clear that if Greenlee and Gila County are going to realize mineral industry development as projected in Table 6, additional water supplies will have to be made available through exchange with water users in other counties.

The mineral industry in Graham County is projected to emerge as a large water user as new mines are developed. Even though the high projection indicates total water use less than dependable water supplies, the mineral industry is faced with a number of complex physical and legal issues in developing supplies to meet the future demands because most water available to Graham County is water from the Gila River decreed to other users.

In Cochise County, mining and mineral processing will continue as a major nonagricultural water user. However, it is not anticipated that the water supply situation for nonagricultural users will be as severe as in other central Arizona counties.

On a statewide basis, maximum increases of mineral industry water depletions for the year 2020 are projected at over six times current depletions while the low projections for that year indicate a doubling of depletions.

File

San Carlos Indian Reservation

Peridot Mine

Inspection Report
B75-2

David D. Rabb
John S. Vuich

At the Request of

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## Summary and Recommendations

A visit was made to the San Carlos Indian Reservation for the purpose of assisting the tribe in increasing the yield of gem quality peridot from their mine near Peridot, Arizona. A small quantity of as-mined ore was brought back to the Arizona Bureau of Mines laboratories for examination and experimentation. Our conclusions and recommendations are as follows:

1. The peridot (olivine) masses are naturally occuring, small granular crystals and blasting and crushing methods now in use probably have little influence on the particle size of most of the peridot liberated from the rock masses.

2. Attempts should be made to identify those areas where large quantities of peridot probably occur and use special care in blasting the rock in these areas. Secondary breakage methods suggested include the use of such items as an hydraulic hammer and a series of jaw crushers. Optional rock-splitting and rock cutting methods are also recommended.

3. Some attempt should be made to replace irregular hand sorting in the working pits with a crush screening operation in order to separate the finer sizes of peridot into several size fractions.

4. Uses for the finer size fractions (decorative sand, etc.) should be developed in order to yield an economic return from the fine sizes now discarded.

## Introduction

On July 9, 1975, Stephen A. Szadek and Peter Cooper, both of the American Indian Consultants, Inc., of Scottsdale, Arizona, visited the Arizona Bureau of Mines in order to define the problems of the San Carlos Indian tribe in recovering gem quality peridot from their mine near Peridot, Arizona. Subsequently, Mr. Szadek arranged for Bureau personnel to visit the peridot mine near San Carlos, Arizona, on the San Carlos Apache Indian Reservation. This visit to San Carlos took place on July 21, 1975.

The purpose of the Bureau personnel visit, was to meet the tribal personnel associated with the mining activity and to inspect the site, the mining methods and the recovered product. See Appendix I for a list of personnel.

This report covers (1) the geology of the area plus recommendations for further geologic studies and
(2) observations and recommendations regarding the mining and peridot recovery.

## General Geology

The following description of the general geology and origin of olivine (peridot) occurrences on Peridot Mesa is a synopsis of the published reports of Broomfield and Shride (1956), Lausen (1927), and a cursory field examination by the authors.

Peridot Mesa is capped by a mafic (magnesium-iron rich), commonly vesicular, lava flow. In more definitive terms this lava flow may be described as an olivine basalt. The source for this particular volcanic flow is a small vent in the southwest corner of the mesa. A magma chamber is theorized to underlie the region. During the cooling of the magnesium rich portion of the magma, olivine crystals began to form early, collecting in a layer as a granular "mush". The vent which had pierced the overlying volcanic ash, gravels, and lake-bed rock layers eventually became clogged. Internal pressures increased to where some of this crystalline, granular mush was blown out into the air in violent eruptions as olivine "bombs". These bombs (nodules) fell to their resting place in the ash beds. The subsequent outpouring of lava carried angular to rounded fragments of granular olivine. Still liquid, the lava flow could not support the nearly solid, granular olivine fragments. These fragments settled near the base of the flow and their distribution diminished with distance from the vent. Excess amounts of magnesium and silica in the cooling lava's residual liquids, solidified as single and generally larger, olivine crystals. These crystals are set directly in the lava matrix or in some of the gas holes (vesicules).

Figure 1 depicts a very generalized cross sectional sequence of geologic events which led to the placement of olivine mineralization at Peridot Mesa. It is not known if the Peridot Mesa flow is regionally unique in the quantity of contained olivine. The true extent of this flow also remains undetermined. Another regionally significant geologic feature is the presence of other volcanic flows, similar in appearance to the Peridot Mesa flow, that also are underlain by light-colored volcanic ash and lake-bed sedimentary rocks. Although these volcanic flow rocks may be closely related in age to the Peridot Mesa flow, it has not been demonstrated that their vent sources were from the same magma chamber or from one of similar chemistry.

## Economic Geology

A primary objective of "olivine mining" is the recovery of the semi-precious gemstone peridot. Since much of the olivine is in a granular, course sand-size form, it would be beneficial to develop a market for this larger mine product, presently considered as waste. Indeed, the crushed lava rock product from a full scale mining operation, may be stock-piled as crushed rock for construction purposes.

If granular olivine products such as decorative sand, chemical reagent, industrial or fertilizer derivities can be developed, we need to know if there are enough ore reserves to supply a particular market. For the purposes of a very rough estimation, that portion of Peridot Mesa considered to contain potentially mineable quantities of granular olivine covers approximately four square miles. It is assumed that the average lava flow thickness is ten feet, of which the lower four feet constitutes the average "ore horizon" thickness. Further assumptions include: (1) that 30 percent of the ore horizon is granular olivine, and (2) that the volume of material in cubic feet per short ton is 11.0 and 9.5 respectively for the whole rock and the granular olivine product. Using these figures, a possible reserve of 14 million tons of olivine is contained in Peridot Mesa with the mining of 100 million tons of the basalt host rock. Since this flow is outcrop, the average overburden cover is anticipated to be six feet, which indicates a stripping ratio of 1.5:1.

The assumed data in the foregoing calculations is not expected to be consistant over the extent of the lava flow. For exploration and optimum mining purposes, all zones and/or other lava flows containing abundant granular olivine fragments need to be delineated. Three options, either used separately or in combination, are suggested for locating areas containing large quantities of olivine.

When olivine granules occur at or near the surface they are often visibly identifiable as soil particulate matter or as sand granules in ant hills. Larger crystals washed into nearby drainages can be used to trace the location of the source material. Non-professional gem hunters often employ these methods as a primary prospecting technique.

Geologic mapping accompanied by systematic drilling of shallow hole tests is a second alternative. Of the three options, this method would be the more expensive to perform, but it would provide the greatest benefit since mineral targets may be defined and the drill test is capable of blocking out (proving) "ore bodies".

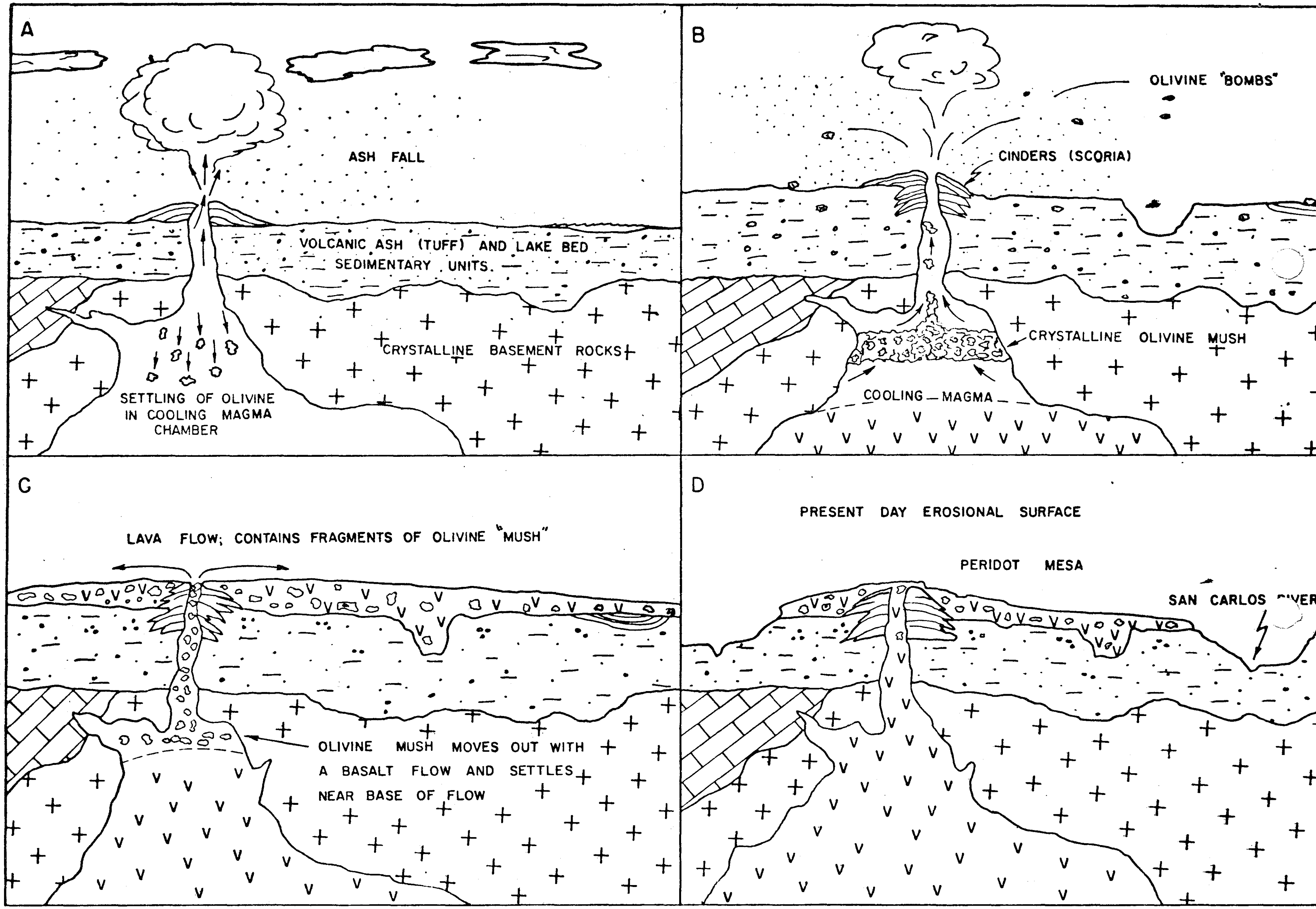


FIGURE I. Generalized geologic cross sections showing probable origin and emplacement of olivine basalt. Sequence from oldest (A) to youngest (D). View is northerly.

A third option consists of systematic geochemical sampling. During the field examination, the author collected samples of the basalt host rock and requested a chemical analysis for the quantity of contained silica ($SiO_2$) and magnesia (MgO). The samples were carefully crushed and hand selected to ensure that they were free of olivine. For comparison, two samples of olivine "free" basalt from the Tucson area were also tested. The results of this chemical analysis and some of the author's comparative calculations are listed below as Table 1.

Table 1

Whole Rock Chemical Analysis

| Sample # | Location | % $SiO_2$ | % MgO | Ratio $SiO_2$/MgO |
|---|---|---|---|---|
| 1 | Peridot Mesa - main pit | 46.6 | 7.15 | 6.5:1 |
| 2 | Peridot Mesa - hilltop outcrop | 47.5 | 9.20 | 5.2:1 |
| 3 | Peridot Mesa - pit near mesa rim | 46.3 | 8.50 | 5.5:1 |
| 4 | Tucson Area - olivine "free" basalt | 55.2 | 3.25 | 17.0:1 |
| 5 | Tucson Area - olivine "free" basalt | 58.0 | 2.50 | 23.0:1 |

From the analysis results listed in Table 1, it would seem reasonable to assume that basalt containing abundant olivine is slightly impoverished of silica and slightly over-saturated with magnesia. When a comparison of the ratio of silica to magnesia is made, the results are even more significant. Ratios for the olivine-deficient basalt contrast with the olivine-rich basalt be nearly a factor of 4. Although not conclusive, it would appear that a whole rock chemical analysis for silica and magnesia contents may be useful exploration guide.

A more careful and detailed study of this method is suggested before accepting this weak statistical analysis of a limited number of samples. In addition to chemically analyzing other "ore" horizon basalts, non-mineralized basalts should be collected from nearby areas for comparison.

If the theory remains valid, we might expect a ratio of $SiO_2$:MgO of less than 7:1 to be from basalt rocks containing abundant olivine; a ratio of 7:1 to 15:1 is of questionable significance; and a ratio greater than 15:1 may indicate a basalt with little or no visible olivine.

## Mineralogy

Chrysolite - olivine, commonly called peridot from the French name for the mineral, is an iron - magnesium silicate, $2(Mg,Fe)O \cdot SiO_2$; relatively infusible, transparent (to translucent), hard (6.5 to 7, harder than file steel), glass. It is moderately heavy, density 3.25 to 3.45, depending upon the iron content.

## Occurrence

The gem olivine material generally occurs as aggregate congregations or granular masses, loosely held together in irregular but flat-sided, sharp edged nodules. The formation of these masses was discussed in the geology section of this report.

After a study of the crystallized masses and microscopic examination of a thin-section, the conclusion is that the dynamite used in mining the rock has little or no effect on the size of the peridot crystals recovered. Sometimes, it is reported, during mining, an area is encountered in which the crystals are much larger. The masses consist of crystal aggregates of half-inch to an inch or larger and virtually none of the finer grain fraction. Such areas containing prize crystals are difficult to predict while mining but, when located, special care should be taken prior to secondary breakage. Other than sledge hammers or jaw crushers, methods available to reduce the size of this material might include a diamond saw, a quarry-type wire saw, a screw-type mineral sample splitter, or tension splitting by a high intensity electric charge (called electro-splitting). Another potentially suitable rock splitter is a commercial hydraulic hammer. An example of a typical hydraulic hammer is the Model 77 Hy-Ram produced by Allied Steel and Tractor Products, Inc., 19200 Cranwood Parkway, Cleveland, Ohio, 44128. A product description of this particular hydraulic hammer is included as Appendix II.

## Screen Analysis

A screen analysis of a roughly representative sample of granular material taken during the mine visit is shown in Table 2.

Table 2 - Screen Analysis

| Size | Weight % | Remarks | Min Size MM |
|---|---|---|---|
| Plus ¼ inch | 1 | pea size | 5.64 |
| Minus ¼ inch, plus 6 mesh | 8 | about 0.1" | 3.74 |
| Minus 6 mesh, plus 10 mesh | 20 | | 2.16 |
| Minus 10 mesh, plus 20 mesh | 46 | pin head size | 1.04 |
| Minus 20 mesh, plus 65 mesh | 15 | | 0.20 |
| Minus 65 mesh | 10 | salt grain size and smaller | |
| | 100 | | |

This material was practically all pure, clean, clear olivine (peridot) and represents roughly the sizes of the sand material that might be expected from a crushing-screening operation.

Roughly half the material is minus 10 plus 20 mesh or about pin head size. One fourth of all this material is smaller than 20 mesh or approaches the size of salt or sugar grains.

Mining Observations

Individual Tribal members mine the peridot containing rocks from 10 or 15 shallow open pits or cuts in the basalt lava flow which forms the top or cap of a large mesa southwest of San Carlos.

The deposit is relatively shallow (10 - 15 feet) and flat lying. Overburden material is first uncovered by bulldozing, scraping, and/or ripping the surface. Hand sorting is the common practice for separating the gem quality material.

In three places a shallow (4 feet to 8 feet), horizontal retreating bench has been mined. The benches are prepared for blasting by drilling standard 1½ inch holes with a jack hammer vertically to a depth of from 3 to 5 feet. The irregularly spaced holes noted during the visit averaged about 5 feet apart. The drill operator said the holes were loaded with 3 or 4, maybe 5 sticks of explosive of 65 percent dynamite and fired simultaneously.

No sequence blasting has been practiced. For this type of work, it would seem that the blasting technique includes a very heavy load of comparatively high energy explosive. The relatively fine fragmentation and wide scatter of "fly" or throw-out material illustrate the violence of the blasts. A sequential or timed blast that incorporates millisecond delays between adjoining holes would be better.

It is suggested that a more even fragmentation could be effected by smaller charges of a lower brisance explosive, say 3 sticks of 40 percent dynamite. Further it is suggested that the holes be made a little deeper, say 6 feet, and be bottom loaded so as to attain more lift. It might be advisable to put 1 stick of 60 percent in the bottom and then 3 sticks of the 40 percent and break more rock for less money and less drilling.

Recommendations

Mining of peridot at the San Carlos Indian Reservation is a small scale operation. This operation is characterized by irregular production, principally by hand labor, with low capital investment and relatively low returns. There is no utilization of by-products. If a larger production of peridot is desired it is suggested that several stages of crushing would be most effective. Commencing with about 12 inch feed to a Blake jaw crusher, the 4 inch product could then feed a 6 inch crusher. A half inch screen could be installed ahead of each crusher as shown in Figure 2 to remove the fine material.

Handpicking the screen undersize and the final crusher product as it is transported along a conveyor belt would be the final step in gem stone sorting. If the crystals are free from imperfections and are large enough to work, the fine clear green varieties are in demand as semi-precious gem stones with values of 10 to 40 dollars per carat, uncut.

If a fine olivine sand product were desired, another screen could handle the reject from the conveyor belt and separate the fine olivine crystals at any desired size. Olivine sand is used principally as a refractory material in fire brick and foundry sand and in the production of magnesium phosphate (fertilizer). Other possible uses include a sharp-edged grit for abrasive

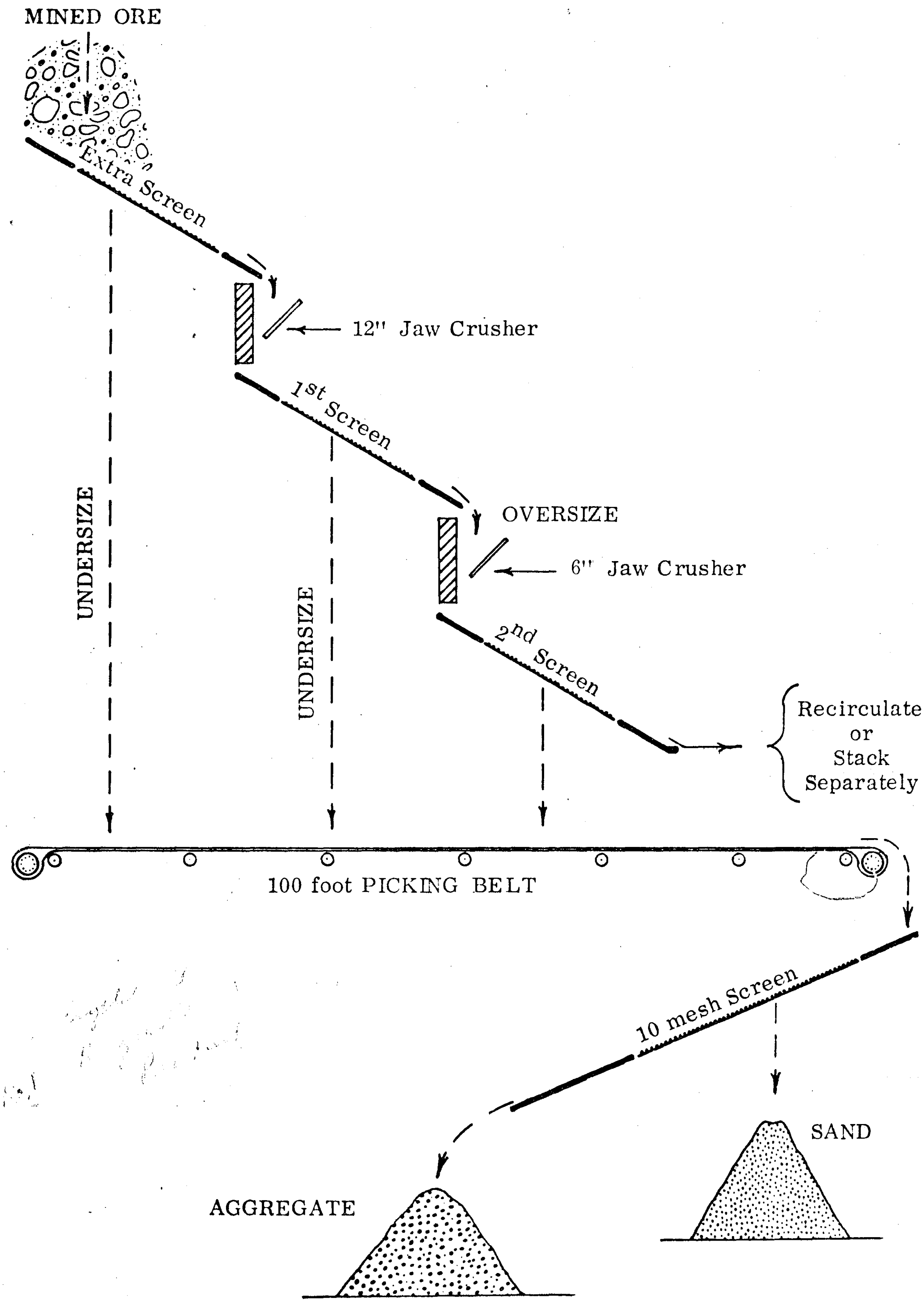


Figure 2. "Suggested Crushing and Screening Flowsheet for Peridot Ore"

powders or sand paper, or as a non-reactive, easily cleansed sand filter bed. Another possible use is as a filler or "propping" agent in hydrofracking. The higher density may prove advantageous under certain conditions. Usually, however, in deep hydrofracking, the oil well operators perfer rounded sand grains as the "propping" agent to hold the cracks open after fractures occur. In construction, the color and hardness of the olivine could result in a very attractive addition to decorative cements for assorted masonry concrete forms.

The crushed basalt in the reject has a potential use as railroad ballast, or construction aggregate as clean, dry, uniformly sized product.

A lower strength dynamite is suggested with modified bottom loading and sequential time-delay blasting.

Concerning the geology, a geological and engineering study is recommended to determine mining feasibility, development costs, production costs, and product sales price. Bulk samples of granular olivine should be sent to a research-testing laboratory to determine the feasibility of bulk, pilot-plant processing for potential market products. Marketing research should ensure potential product markets prior to a larger scale development.

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## APPENDIX I

## PERSONNEL LIST

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